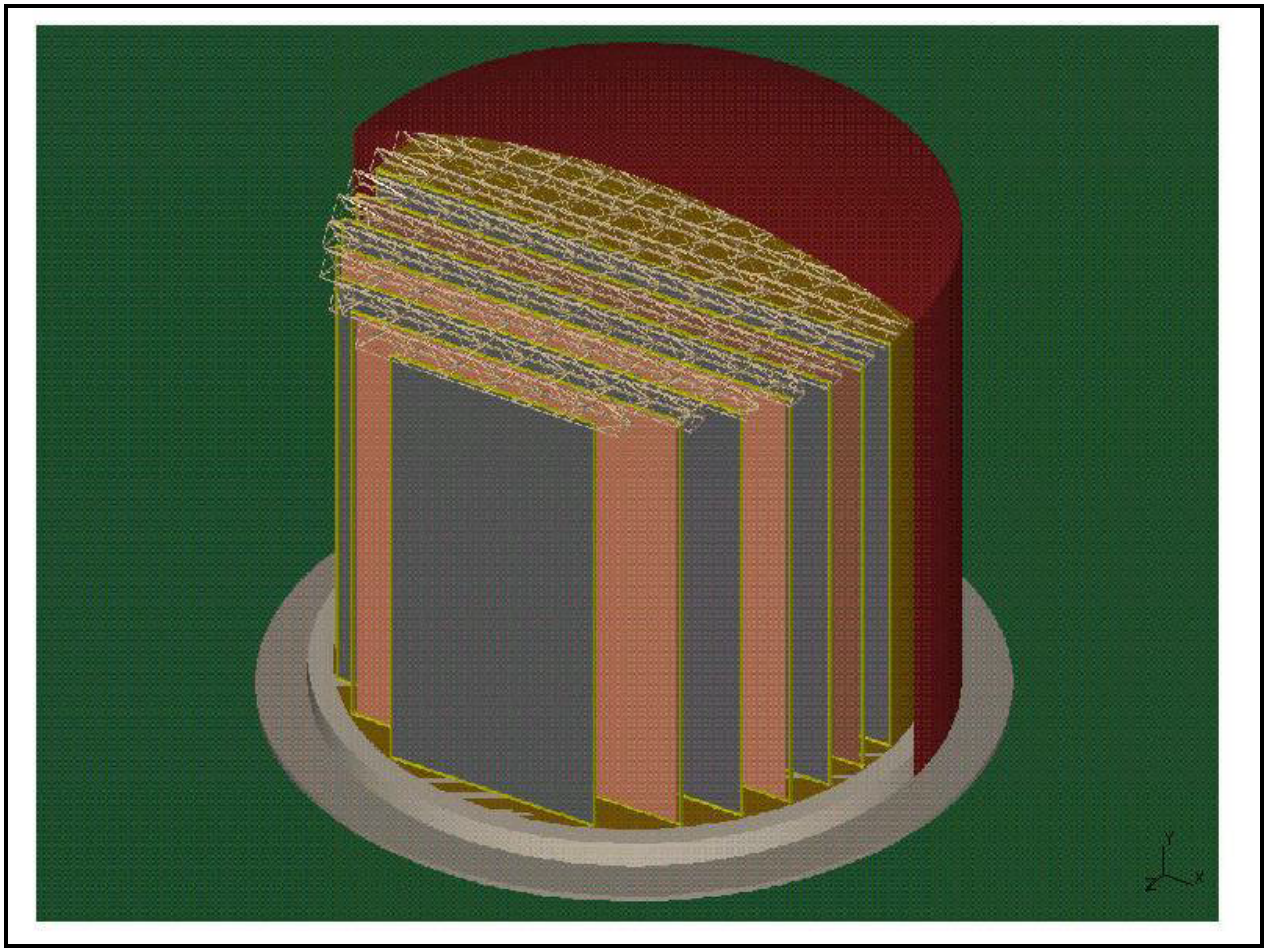
Fermilab	**Particle Physics Division** **Mechanical Department**

Engineering note number:		Date:	11/30/2004

Experiment	**FLARE**
Project	Inner tank
Author(s)	Rafael Silva (FNAL)
Reviewer(s)	Bob Wands (FNAL)
Abstract	Preliminary FEA of the FLARE inner tank



Model by Chuck Grimm

1. Objective

The goal of this analysis is to indicate if the most desirable basic design ideas for the inner tank are feasible. It seems practical to have the stereo wires supported directly from the vertical cylindrical walls of the tank. It is also much better to have a flat roof that provides the shortest path for the signals from the wires. The electronics at the top of the roof should also be accessible to people. A space frame structure supporting the roof seems to provide a good solution, and that is what is going to be assumed. It would also be best if the vertical cylindrical walls of the tank can support the full load without the need of additional structures or reinforcements.

The inner tank will have at least 3 different loading conditions: full of liquid (for the hydrostatic test), empty and with the wire load (at the end of the assembly), and full of liquid plus the load from the wires.

First, a 1" wall is assumed and a hydrostatic load equivalent to the weight of the argon is applied. From these results, an appropriate wall thickness is devised. Then the wire loads are applied and stresses and buckling checked.

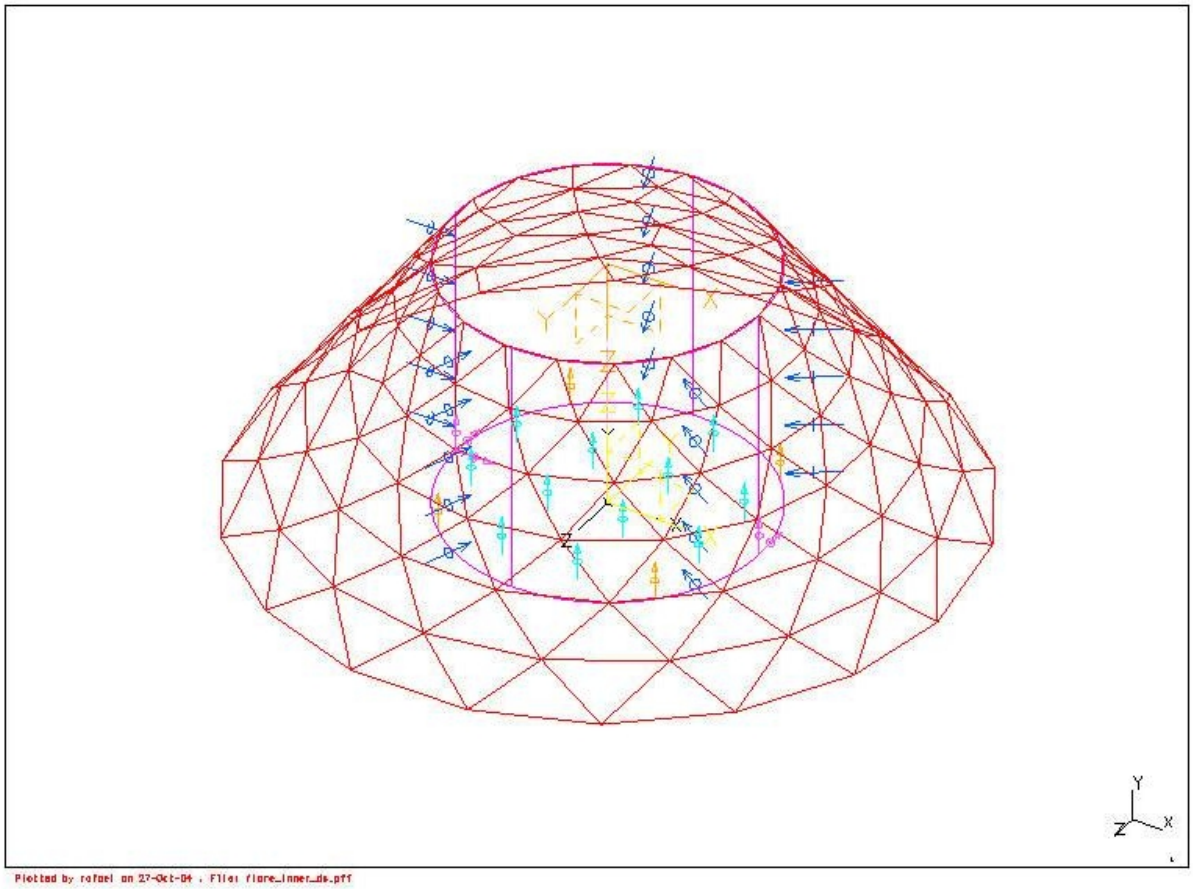
2. Parameters Used

Program: I-DEAS v.9m3 / Simulation.
Analysis: Linear Static,
Analysis: Linear Buckling.
Material properties - 9%Ni steel:
density = 7.32986×10^{-4} lbf.sec^2/in^4
η = 0.3
E = 2.88×10^7 psi
Elements: thin shell parabolic quadrilateral, average mesh size about 4'.

3. Boundary Conditions

3.1. Hydrostatic load

Bottom of walls is supported vertically only with one point fixed. Load is applied according to data surface defined, as shown below. Gravity is also applied.



3.2. Wire load

Wire load and gravity are applied. Second, same load but bottom of the tank is fixed and top is restrained in the horizontal directions, free to move vertically.

The space between the wire planes and, consequently, between the space frames is 20 ft. Calculating the load per foot on the longest space frame span at the top of the tank:

Roof: 1/4" plate, 10.2 lb/ft^2 x 20 ft = 204 lb/ft
Cover: 1/8" plate, 5.1 lb/ft^2 x 20 ft = 102 lb/ft
Perlite: 10 lb/ft^3 x 4 ft thick = 40lb/ft^2 x 20 ft = 800 lb/ft
Wires: 114,271lb / 130.5 ft = 876 lb/ft
Equipment: 50 lb/ft (guess)
Total: 204+102+800+876+50= 2032 lb/ft

Looking at the Vulcraft catalog for a truss that would work as a space frame (to estimate the weight):

ECONOMICAL JOIST GUIDE

Combined K, VS, LH & DLH Series Load Table

82' LENGTH (Cont.)

52DLH11	359	225	34
52DLH12	400	246	37
48LH13	402	238	38
44LH14	446	231	31
52DLH13	486	298	31
60DLH14	514	362	31
44LH15	524	271	31
52DLH14	556	333	35
60DLH15	604	423	34
52DLH15	624	375	30
64DLH16	659	508	36
60DLH16	664	477	38
52DLH16	673	411	44
48LH17	706	397	47
52DLH17	775	476	48
64DLH18	857	668	46
60DLH18	880	613	50
68DLH19	926	783	52

83' LENGTH

44LH9	221	114	18
44LH10	383	125	19
44LH11	384	136	21
44LH12	323	166	25
48LH12	329	185	24
52DLH11	354	220	25
52DLH12	396	240	27
44LH14	426	223	31
60DLH13	457	332	28
56DLH13	473	311	30
52DLH13	480	291	32
60DLH14	508	358	30
44LH15	512	261	31
52DLH14	549	325	35
60DLH15	596	417	34
56DLH15	611	392	37
60DLH16	656	466	38
52DLH16	666	401	44
48LH600	383	41	
60DLH17	764	539	46
52DLH17	766	465	48
64DLH18	856	605	48
60DLH	18	870	508
68			
68DLH19	914	765	54

84' LENGTH

44LH9	216	110	18
44LH10	238	121	19
44LH11	258	131	21
44LH12	315	160	25
52DLH10	319	196	23
48LH12	322	179	24
52DLH11	350	215	25
52DLH12	391	234	27
44LH14	425	215	31
56DLH13	467	304	30
52DLH13	475	284	32
44LH15	500	252	31
60DLH14	502	345	31
48LH15	521	285	36
52DLH14	543	317	37
60DLH15	589	407	34
56DLH15	604	383	38
60DLH16	648	455	30
52DLH16	657	397	44
48LH17	675	371	47
60DLH17	745	517	46
56DLH17	751	485	46
52DLH17	757	454	52
64DLH18	856	622	48
60DLH18	850	584	50

84' LENGTH (Cont.)

64DLH19	992	746	54

85' LENGTH

44LH9	211	108	18
44LH10	233	117	19
44LH11	252	127	21
44LH12	308	155	25
52DLH10	315	192	24
52DLH11	346	210	25
52DLH12	386	229	27
44LH14	415	207	31
56DLH13	462	297	30
52DLH13	469	277	32
44LH15	488	243	31
60DLH14	495	336	31
48LH15	510	278	36
52DLH14	535	310	37
60DLH15	582	397	34
56DLH15	595	374	38
60DLH16	640	444	30
56DLH16	644	416	41
52DLH16	650	388	45
48LH17	660	398	47
72DLH17	660	554	38
60DLH17	736	505	45
56DLH17	742	474	46
52DLH17	748	443	52
64DLH18	846	607	47
60DLH18	840	570	53
68DLH19	951	729	54

86' LENGTH

44LH9	207	103	18
44LH10	228	113	19
44LH11	247	123	21
44LH12	300	149	25
52DLH10	312	187	24
52DLH11	342	205	26
52DLH12	382	223	27
44LH14	405	200	31
56DLH13	455	290	30
52DLH13	463	271	33
60DLH14	490	329	32
48LH15	499	269	36
52DLH14	530	302	37
60DLH15	575	388	36
56DLH15	589	366	38
52DLH15	595	341	41
56DLH16	636	408	37
64DLH16	638	461	38
60DLH16	633	434	40
56DLH16	636	407	41
52DLH16	642	379	45
48LH17	646	346	47
72DLH17	662	551	38
60DLH17	727	493	45
56DLH17	733	463	48
52DLH17	739	433	52
64DLH18	816	627	46
60DLH18	839	557	53
68DLH19	940	712	54

87' LENGTH

44LH9	202	99	18
44LH10	223	110	19
44LH11	242	119	21
44LH12	293	144	25
52DLH10	308	183	24
52DLH11	338	200	26
52DLH12	377	218	27

87' LENGTH (Cont.)

44LH14	396	193	31
48LH14	425	227	32
56DLH13	451	283	31
52DLH13	458	264	33
44LH15	466	227	31
60DLH14	485	321	32
48LH15	488	260	36
52DLH14	524	295	37
64DLH15	562	403	35
56DLH15	583	357	38
52DLH15	588	333	41
64DLH16	621	451	38
56DLH16	629	397	41
52DLH16	635	370	45
72DLH17	674	538	39
60DLH17	719	482	45
56DLH17	725	452	48
52DLH17	730	423	52
68DLH18	807	613	46
60DLH18	830	544	50
68DLH19	929	695	54

88' LENGTH

44LH9	198	95	18
44LH10	218	105	19
44LH11	236	115	21
44LH12	287	139	25
52DLH10	305	179	23
52DLH11	334	195	26
52DLH12	373	213	27
44LH14	397	187	31
48LH14	416	220	32
56DLH13	446	277	31
52DLH13	453	258	33
44LH15	456	219	31
60DLH14	479	314	32
52DLH14	518	289	37
64DLH15	545	392	35
60DLH15	562	370	37
56DLH15	582	325	41
64DLH16	614	440	38
52DLH16	627	362	45
72DLH17	666	526	41
60DLH17	711	471	45
56DLH17	716	442	48
52DLH17	722	413	52
72DLH18	780	594	47
68DLH18	797	569	48
60DLH18	820	532	50
72DLH19	915	674	54
68DLH19	918	680	55

89' LENGTH

48LH10	212	112	18
48LH11	229	120	20
52DLH10	301	175	23
52DLH11	330	191	26
52DLH12	369	209	28
48LH14	407	212	32
52DLH13	448	253	33
60DLH14	474	307	32
52DLH14	512	282	38
64DLH15	539	385	34
60DLH15	556	362	37
52DLH15	575	318	41
64DLH16	607	431	38
60DLH16	611	405	40
52DLH16	620	354	45
72DLH17	659	514	41
60DLH17	703	460	45
56DLH17	708	432	49

89' LENGTH (Cont.)

52DLH17	714	404	52
72DLH18	771	581	47
68DLH18	788	556	48
60DLH18	811	520	53
72DLH19	905	659	54
68DLH19	908	665	55

90' LENGTH

48LH10	208	108	18
48LH11	225	117	20
52DLH10	298	171	24
52DLH11	327	187	26
48LH13	338	175	29
52DLH12	366	204	29
48LH14	399	206	32
60DLH13	422	282	30
56DLH13	436	266	31
52DLH13	443	247	34
60DLH14	468	300	32
52DLH14	507	276	38
64DLH15	533	376	34
60DLH15	550	354	37
64DLH16	600	421	39
60DLH16	604	396	40
52DLH16	614	346	45
72DLH17	651	503	40
60DLH17	695	450	46
72DLH18	763	558	46
68DLH18	780	533	48
60DLH18	802	508	53
72DLH19	894	644	54
68DLH19	898	650	55

91' LENGTH

48LH10	204	105	18
48LH11	220	113	20
52DLH10	291	165	24
52DLH11	320	181	26
48LH13	332	170	29
52DLH12	357	197	29
48LH14	390	199	32
60DLH13	417	276	30
52DLH13	433	259	33
48LH15	448	228	36
64DLH14	460	313	32
60DLH14	463	293	34
52DLH14	497	266	38
64DLH15	527	368	35
60DLH15	544	346	37
64DLH16	593	412	39
60DLH16	596	387	42
52DLH16	601	335	45
60DLH17	687	440	46
72DLH18	754	555	46
68DLH18	771	550	48
60DLH18	793	497	53
72DLH19	885	630	54
68DLH19	888	636	55

92' LENGTH

48LH10	200	102	18
48LH11	216	110	20
52DLH10	285	160	24
52DLH11	313	174	26
48LH13	325	164	29
52DLH12	349	191	29
56DLH12	352	209	27
48LH14	383	193	32
60DLH13	412	270	30
52DLH13	424	251	33

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Combined K, VS, LH & DLH Series Load Table

118' LENGTH (Cont.)

64DLH12	295	146	29
60DLH13	301	154	34
64DLH13	310	176	34
60DLH14	332	166	37
64DLH14	354	189	37
68DLH15	391	228	39
60DLH15	392	194	43
64DLH15	407	223	43
60DLH16	428	217	46
68DLH16	463	268	46
60DLH17	493	247	52
72DLH17	505	302	50
64DLH17	527	283	52
60DLH18	556	279	59
64DLH18	608	320	59
68DLH19	696	391	66

117' LENGTH

60DLH12	264	124	29
64DLH12	251	142	29
60DLH13	296	151	34
64DLH13	305	171	34
60DLH14	327	161	37
64DLH14	349	184	37
72DLH15	385	222	38
68DLH15	387	224	41
64DLH15	400	217	43
60DLH16	421	211	46
64DLH16	450	242	46
68DLH16	459	263	46
60DLH17	484	241	52
72DLH17	501	297	50
64DLH17	518	275	52
60DLH18	559	272	59
64DLH18	598	311	59
68DLH18	690	388	60
72DLH19	687	381	67
68DLH19	690	384	67

118' LENGTH

60DLH12	240	121	29
64DLH12	247	138	29
60DLH13	291	147	34
60DLH14	321	156	37
64DLH14	343	179	37
72DLH15	382	218	38
68DLH15	384	220	41
64DLH15	394	211	43
60DLH16	414	206	46
72DLH16	441	257	46
68DLH16	456	259	46
72DLH17	496	292	50
64DLH17	509	266	52
68DLH17	513	294	53
60DLH18	549	266	59
64DLH18	587	304	59
68DLH18	594	333	60
72DLH19	682	374	67
68DLH19	684	377	67

119' LENGTH

60DLH12	236	118	29
64DLH12	243	135	29
60DLH13	286	143	34
64DLH13	295	163	34
60DLH14	316	152	37
64DLH14	337	174	37
68DLH14	340	193	38
72DLH15	378	214	38
68DLH15	381	217	40

119' LENGTH (Cont.)

64DLH15	397	205	43
60DLH16	407	201	46
72DLH16	437	252	46
68DLH16	452	254	46
72DLH17	492	287	49
64DLH17	501	262	52
68DLH17	503	289	53
60DLH18	540	259	59
64DLH18	578	295	59
68DLH18	589	323	60
72DLH19	676	368	67
68DLH19	678	371	67

120' LENGTH

60DLH12	232	115	29
64DLH12	239	132	29
60DLH13	282	139	34
64DLH13	291	159	34
60DLH14	310	149	37
64DLH14	332	171	37
68DLH14	335	190	38
72DLH15	375	211	38
68DLH15	378	213	40
64DLH15	391	201	43
60DLH16	400	196	46
72DLH16	434	248	46
68DLH16	448	250	46
72DLH17	488	282	49
64DLH17	492	255	52
68DLH17	505	284	53
60DLH18	531	255	59
64DLH18	568	288	59
68DLH18	584	321	60
68DLH19	673	365	67

121' LENGTH

64DLH12	225	129	29
64DLH13	286	155	34
64DLH14	326	166	37
68DLH14	334	187	38
72DLH15	372	207	40
68DLH15	375	209	40
72DLH16	430	244	46
68DLH16	444	246	46
72DLH17	484	278	49
68DLH17	501	280	53
64DLH18	559	282	59
68DLH18	579	316	60
68DLH19	667	359	67

122' LENGTH

64DLH12	231	125	29
64DLH13	281	152	34
68DLH13	288	171	35
64DLH14	321	162	37
68DLH14	332	185	38
72DLH15	369	204	40
68DLH15	372	206	42
72DLH16	427	240	46
68DLH16	441	242	46
64DLH17	476	248	52
68DLH17	497	275	53
64DLH18	549	274	59
68DLH18	575	311	60
72DLH19	669	360	67
68DLH19	662	363	67

123' LENGTH

64dh12	228	122	29

123' LENGTH (Cont.)

64DLH13	277	148	34
68DLH13	284	168	35
64DLH14	316	158	37
68DLH14	327	179	38
68DLH15	366	201	42
72DLH15	366	200	41
72DLH16	423	236	45
68DLH16	433	236	46
64DLH17	466	237	52
68DLH17	489	268	53
64DLH18	540	267	59
68DLH18	566	304	60
72DLH19	654	344	67

124' LENGTH

64DLH12	224	119	29
64DLH13	273	144	34
68DLH13	279	164	35
64DLH14	311	154	37
68DLH14	322	175	38
68DLH15	360	196	42
72DLH15	360	197	41
64DLH16	401	203	46
72DLH16	420	232	47
68DLH16	427	230	49
64DLH17	461	231	52
68DLH17	481	262	53
64DLH18	532	261	59
68DLH18	557	297	60
72DLH19	649	339	68

125' LENGTH

64DLH12	221	216	29
64DLH13	269	141	34
64DLH14	306	151	37
68DLH14	317	171	38
68DLH15	354	191	41
72DLH15	350	194	41
64DLH16	394	198	46
72DLH16	416	229	47
68DLH16	420	225	49
64DLH17	454	226	52
68DLH17	474	256	53
64DLH18	523	255	59
68DLH18	549	289	60
72DLH19	643	333	67

126' LENGTH

64DLH12	218	114	29
64DLH13	264	131	34
64DLH14	301	147	37
68DLH14	312	167	38
72DLH15	357	191	41
64DLH16	388	193	46
72DLH16	413	225	47
64DLH17	446	220	52
68DLH17	467	249	53
64DLH18	515	249	59
68DLH18	540	283	60
72DLH18	544	289	59
72DLH19	636	328	67

127' LENGTH

64DLH12	214	111	29
64DLH13	260	134	34
64DLH14	296	143	37
68DLH14	308	163	38
72DLH14	309	166	37
68DLH15	343	182	41

127' LENGTH (Cont.)

72DLH15	354	188	41
64DLH16	382	189	46
72DLH16	410	221	47
64DLH17	439	215	52
72DLH17	461	252	53
64DLH18	507	243	59
68DLH18	532	276	60
72DLH18	540	284	59
72DLH19	633	323	67

128' LENGTH

64DLH12	211	109	29
64DLH13	257	131	34
64DLH14	292	140	37
68DLH14	303	159	38
72DLH14	307	166	37
68DLH15	337	178	41
72DLH15	352	186	41
64DLH16	376	185	46
72DLH16	407	218	47
64DLH17	432	210	52
68DLH17	453	238	53
72DLH17	457	248	53
64DLH18	499	237	59
68DLH18	524	269	60
72DLH18	535	280	59
68DLH19	601	305	67
72DLH19	628	318	67

129' LENGTH

68DLH13	259	145	35
68DLH14	299	155	38
72DLH14	305	163	38
72DLH15	349	182	41
72DLH16	403	215	49
68DLH17	446	232	53
72DLH17	454	244	53
68DLH18	516	265	60
72DLH18	532	276	59
72DLH19	623	313	67

130' LENGTH

68DLH13	255	142	35
68DLH14	294	152	38
72DLH14	303	171	38
72DLH15	347	191	41
72DLH16	401	225	49
68DLH17	439	228	55
72DLH17	451	235	55
68DLH18	508	257	60
72DLH18	528	289	59
68DLH19	593	291	67
72DLH19	619	328	70

131' LENGTH

68DLH13	252	138	35
68DLH14	290	148	38
72DLH14	298	167	38
68DLH15	332	186	41
72DLH15	342	187	41
72DLH16	395	219	49
68DLH17	433	222	53
72DLH17	445	250	53
68DLH18	501	251	60
72DLH18	520	283	59
68DLH19	574	285	67
72DLH19	609	321	70

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131 ft ⇒ 4 x 72DLH18, 59lb/ft (each) = 236 lb/ft
118 ft ⇒ 4 x 64DLH17, 52lb/ft (each) = 208 lb/ft
87 ft ⇒ 3 x 60DLH17, 46lb/ft (each) = 138 lb/ft

Total:
131 ft ⇒ (236 lb/ft + 2032 lb/ft) x 131 ft = 297,108 lb
118 ft ⇒ (208 lb/ft + 2032 lb/ft) x 118 ft = 264,320 lb
87 ft ⇒ (138 lb/ft + 2032 lb/ft) x 87 ft = 188,790 lb

Pulleys:
6582 / side.plane x ~1/2 lb / (pulley + hardware) = 3,300 lb/ side.plane

Not included: cathode planes, field shaping cage.

Total load:

Vertical:
Total load applied to one point, at the top of the wall, at the plane location:
131 ft: 148,554 lb, for the analysis ⇒ 149,000 lb
118 ft: 132,160 lb, for the analysis ⇒ 132,000 lb
87 ft: 94,395 lb, for the analysis ⇒ 95,000 lb

Distributed along the wall (all):
18,902 lb + pulleys, for the analysis ⇒ 22,200

Horizontal, distributed (all): 18,902, for the analysis ⇒ 19,000 lb.

Total vertical load:
[149,000 lb + 132,000 lb + 95,000 lb + (22,200 lb x 3)] x 4 = 1,770,400 lb
Weight of side walls: ~ 2,832,182 lb
Total: 4,602,582 lb

4. Allowable Stresses

The criterion adopted in this note is:

Stress intensity (2 x maximum shear stress)

shall be smaller than

23.7 ksi (*)

(*) Refer to CB&I documentation (which is based on ASME) – see below.

Welds are full penetration, visually inspected and U.T. tested as to allow 100% efficiency.

Stability: Buckling Load Factor (linear buckling) > 4. Published safety factors for buckling vary according to the application. A safety factor greater than 4 seems consistent with what is recommended by Appendix 3, ASME section II, part D., 1995, item 3-600 (c) (1), p.705.

ost metals increase in strength with a decrease in temperature. Some, however, such as carbon steel, suffer an almost complete loss of ductility at low temperatures, making them useless for cryogenic vessel construction. Copper, nickel, aluminum and most alloys of these metals exhibit no ductile to brittle transitions and, therefore, are suitable for cryogenic service. Stainless steel of the 18 per cent chrome, 8 per cent nickel classification also exhibits excellent ductility.

Certain minimum requirements have been established by the ASME Code, API Standard 620 and regulatory bodies in the construction of vessels for ultra-low temperatures.

MATERIALS FOR CRYOGENIC TANKS (THROUGH -450°F)

ALLOWABLE STRESS (PSI)

Material	Designation Number	Pressure Storage (ASME)	Flat-Bottom Storage Tanks CB&I Design Methods
Stainless	A240 Type 304	18,750	22,500
Aluminum	AA5052 AA5086 AA5083	6,250 8,700 10,000	7,100 10,500 13,300
5% Nickel 5% Nickel 9% Nickel	A 645 – A553 Class 1 A353	23,700 23,750	31,700 31,700 31,700

STRESS INTENSITY = 23,700 => MAX. SHEAR = 11,850 PSI

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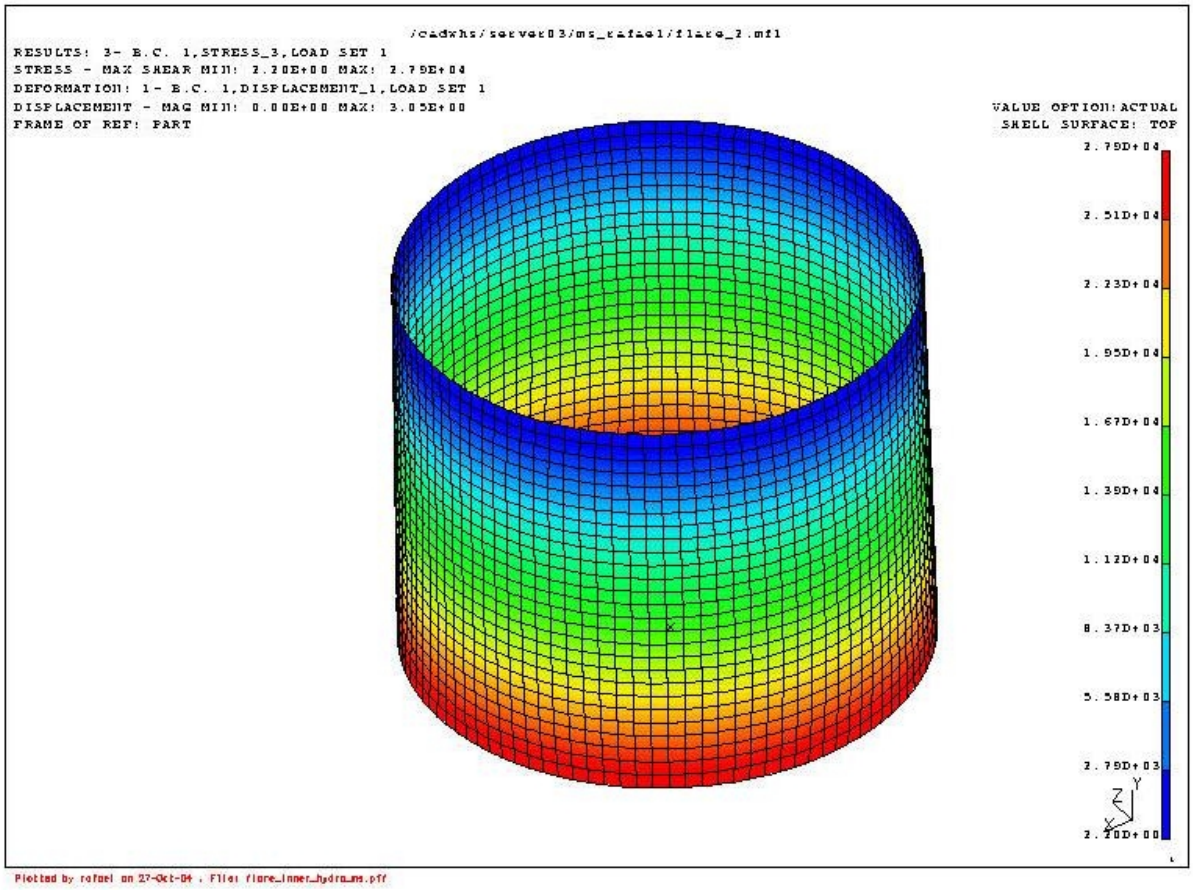
Tank Shells and Insulation

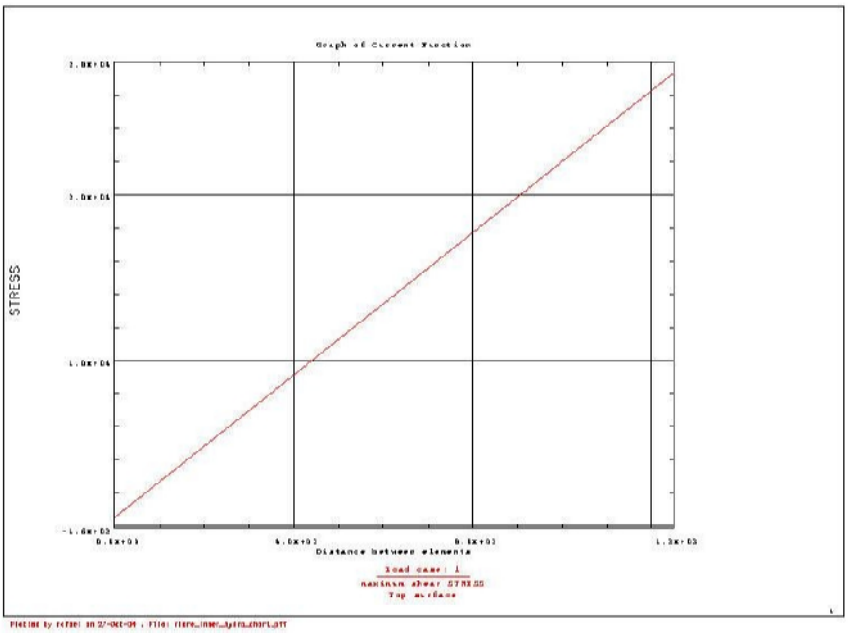
Refrigerated storage tanks and their insulation systems must be designed to work together to assure optimum performance. Low temperature insulation is required for both spherical and flat bottom cylindrical refrigerated storage tanks.

There are three principal types of shell and insulation systems for refrigerated gases: single steel wall (SW), double steel wall (DW), and concrete outer shell with double steel wall interior. Common to both the SW and DW insulation systems is the suspended deck roof insulation system that CB&I introduced in 1966 and load bearing bottom insulation systems. The following portions of this section describe DW, SW, suspended deck roof, and load bearing bottom insulation systems, and the concrete outer shell tanks in more detail.

5. Results – hydrostatic load

With 1” thick wall, stress intensity is 55.8 ksi, maximum deflection is 3.1”.





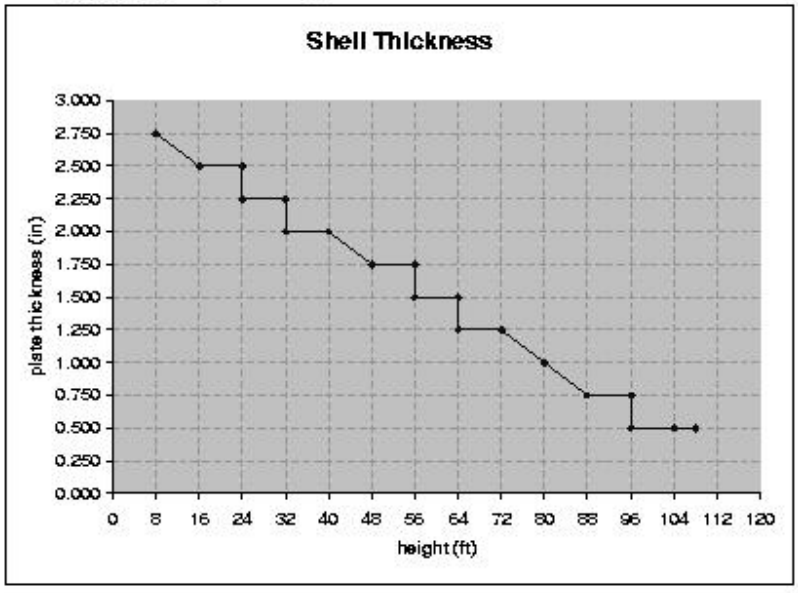
Scaling from these results, the thickness of the wall was increased in 1/4” increments and 1/2” thickness minimum was adopted.

hydro_stress_table_p.xls

I-DEAS 9 m3: Simulation 38287.000 22:12:52
/cadwrks/server03/ms_rafael/flare_2.mf1
chart
SET 1
Group ID : None
Result Set : 3.000 - B.C. 1,STRESS_3,LOAD

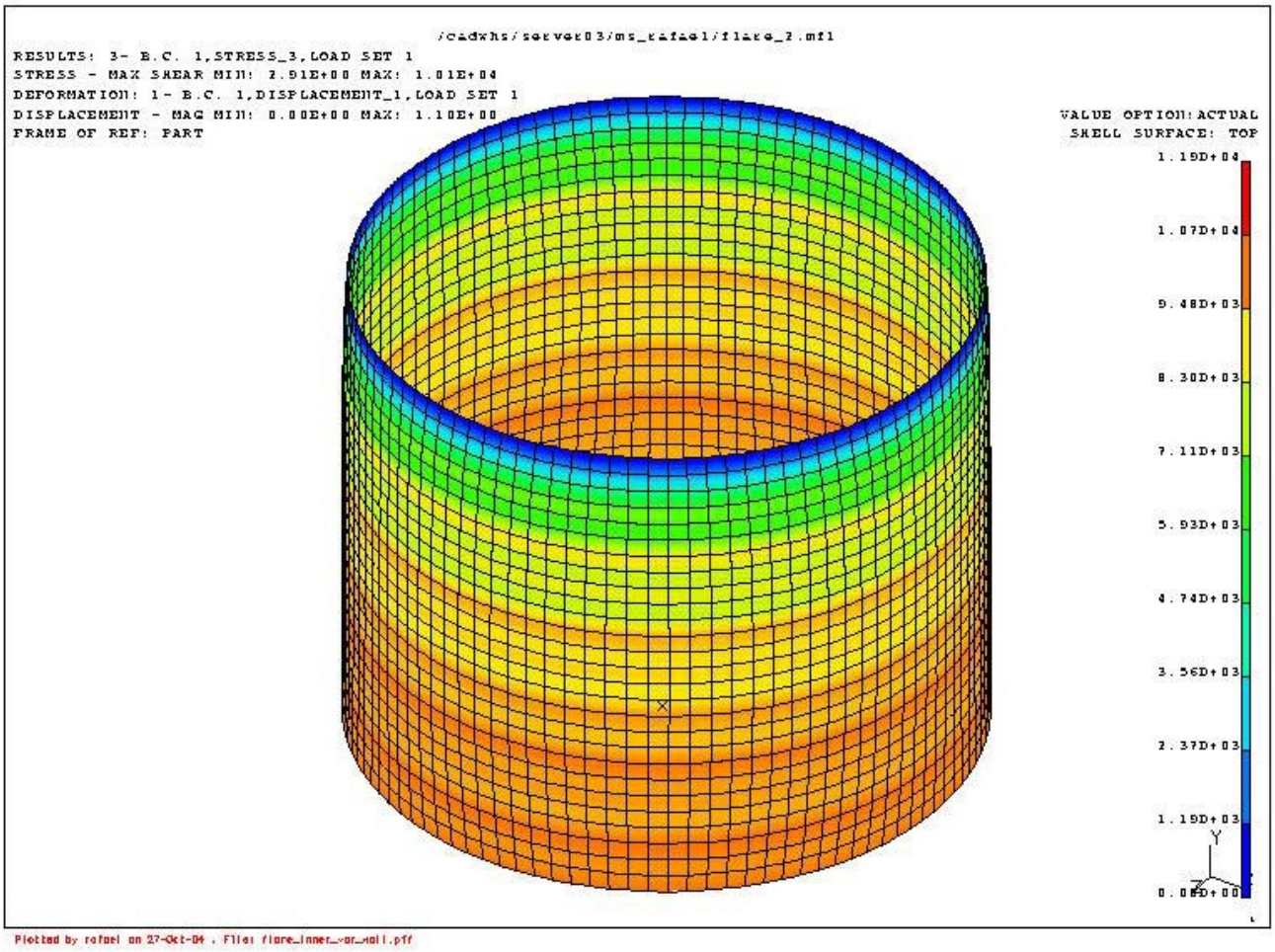
Elem Data	Elem Distance	Elem Max Shear	Elem Req. Thick.	Elem Round Thick.	Even distance from bottom	Shell Thickness	weight
	in	psi	in	in	ft	in	
1	0	5.16 E+02	0.048	0.250	108	0.500	33818
2	48	1.55 E+03	0.143	0.500	104	0.500	33818
3	96	2.58 E+03	0.238	0.500	104	0.500	33818
4	145	3.62 E+03	0.333	0.500	96	0.500	50878
5	193	4.65 E+03	0.428	0.750	96	0.750	50878
6	241	5.68 E+03	0.524	0.750	88	0.750	50878
7	289	6.71 E+03	0.619	0.750	88	0.750	67837
8	337	7.75 E+03	0.714	1.000	80	1.000	67837
9	385	8.78 E+03	0.809	1.000	80	1.000	84796
10	433	9.81 E+03	0.904	1.250	72	1.250	84796
11	481	1.08 E+04	1.000	1.250	72	1.250	84796
12	529	1.19 E+04	1.095	1.250	64	1.250	101755
13	577	1.29 E+04	1.190	1.500	64	1.500	101755
14	625	1.39 E+04	1.285	1.500	56	1.500	118714
15	673	1.50 E+04	1.381	1.750	56	1.750	118714
16	721	1.60 E+04	1.476	1.750	48	1.750	118714
17	769	1.70 E+04	1.571	1.750	48	1.750	135673
18	817	1.81 E+04	1.666	2.000	40	2.000	135673
19	865	1.91 E+04	1.761	2.000	40	2.000	135673
20	913	2.01 E+04	1.856	2.000	32	2.000	152633
21	961	2.12 E+04	1.951	2.250	32	2.250	152633
22	1009	2.22 E+04	2.047	2.250	24	2.250	169592
23	1057	2.32 E+04	2.142	2.500	24	2.500	169592
24	1105	2.43 E+04	2.237	2.500	16	2.500	169592
25	1153	2.53 E+04	2.333	2.500	16	2.500	186551
26	1201	2.63 E+04	2.428	2.750	8	2.750	186551
27	1250	2.74 E+04	2.523	2.750	8	2.750	2832182

Function Dataset : Current
Report Type : XY - Graph Units: IN
Result Type : STRESS
Frame of Reference: Part Data Component: Max Shear
Surface Type : Top



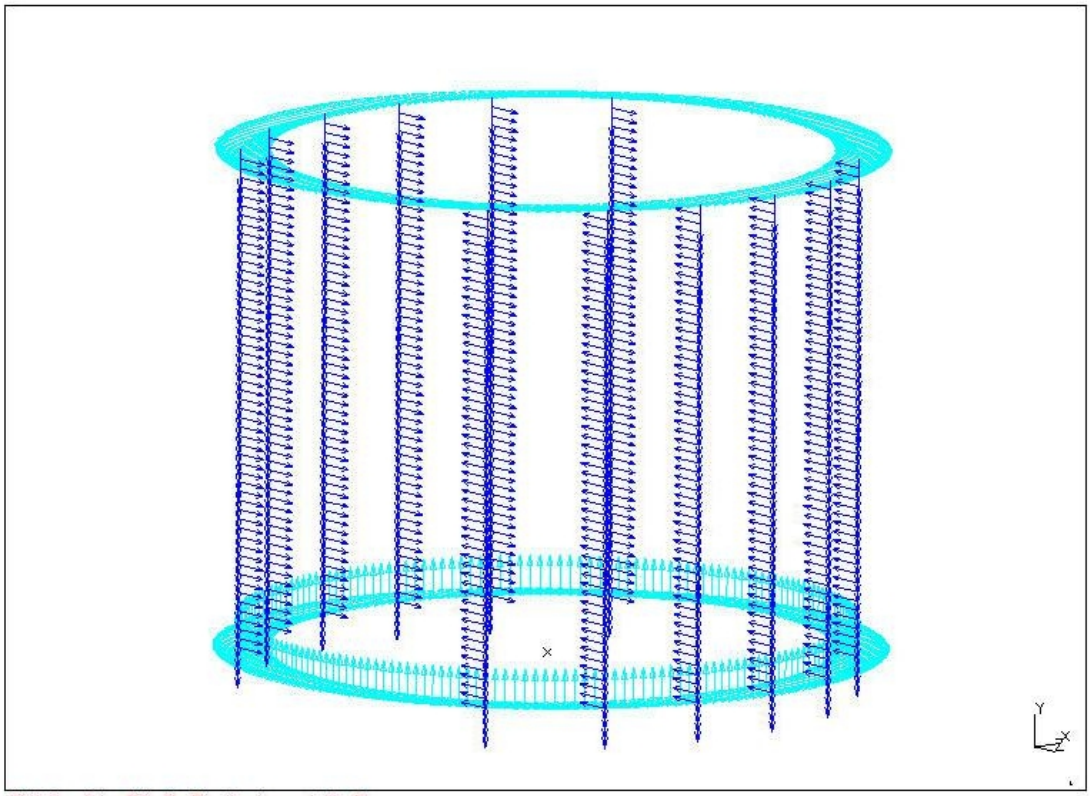
11/23/2004 3:10 PM 1 / 1

With variable thickness wall, **stress intensity is 20.2 ksi,** which is smaller than 23.7 ksi. Maximum efficiency would show the whole tank in orange but the variation in thickness happens in discreet increments rather than continuously and, at the top, the minimum thickness was set to 1/2". Maximum deflection is 1.1".

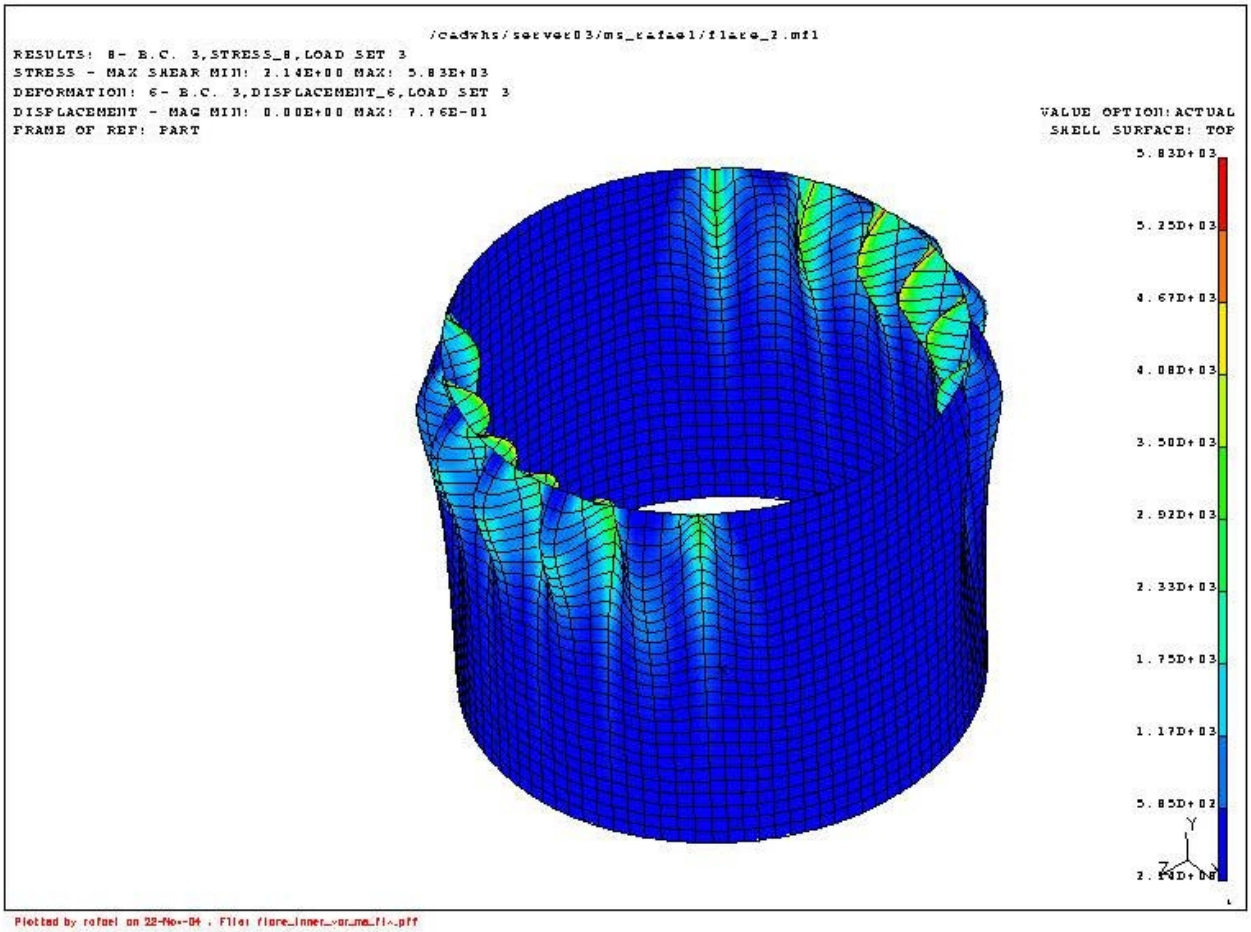


6. Results – wire load

Wire load + gravity, bottom of the tank is fixed and top is restrained in the horizontal directions, free to move vertically.



Plotted by rafael on 17-Nov-04 , File: flare_inner_var_bc_fi~.pff



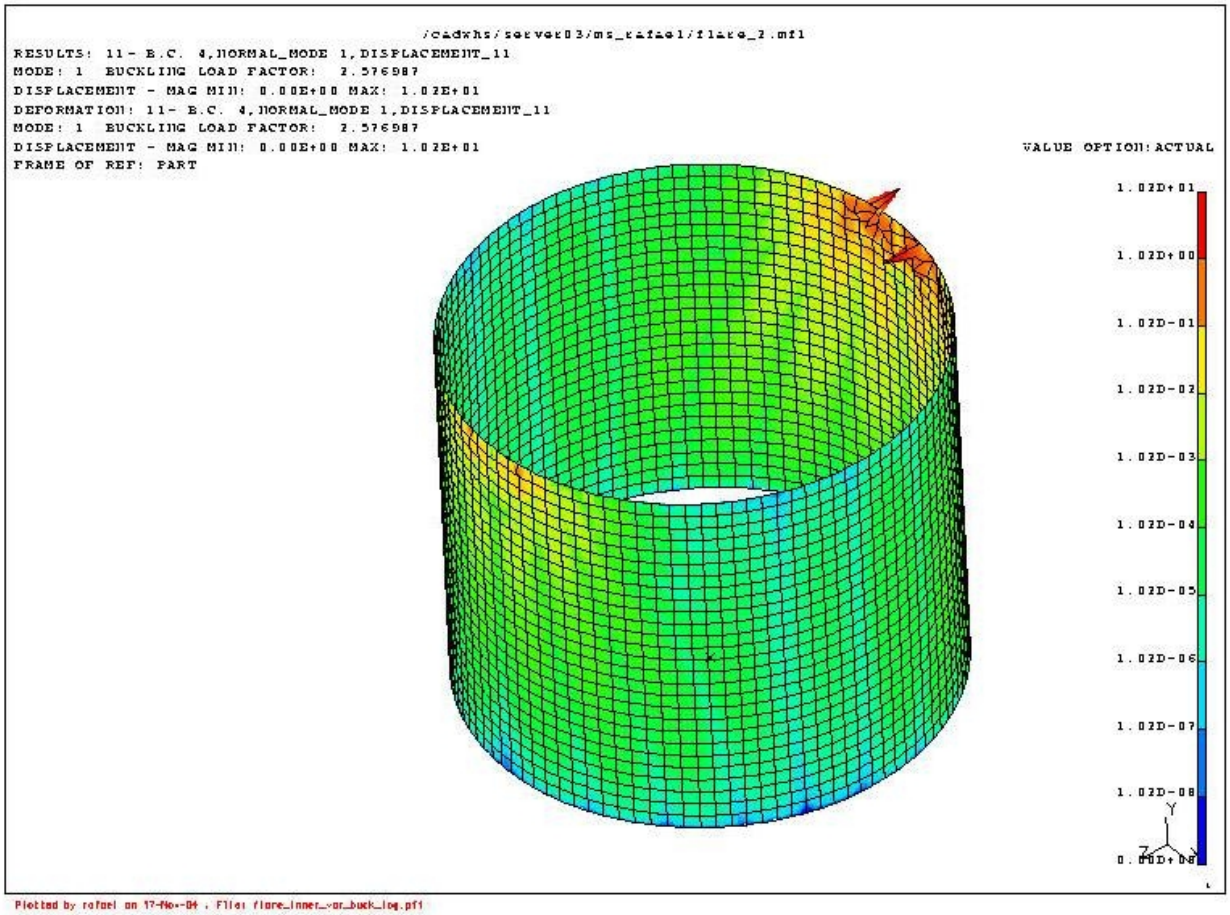
Plotted by rafael on 22-Nov-04 , File: flare_inner_var_ma_fi~.pff

The results are acceptable: **stress intensity is 11.7 ksi**, and maximum deformation is 0.78". That indicates that if the top and bottom are braced appropriately and not allowed to move inwards, the walls would be fine. Hence the space frame needs to provide also bracing for the top and additional bracing is required at the bottom. Further and more detailed analysis is required to determine the bracing needed.

Note that the higher stresses happen at the top, where the plate thickness is 1/2" only.

7. Results – stability under wire load

A linear buckling analysis was performed. Same load (wire load + gravity), bottom of the tank is fixed and top is restrained in the horizontal directions, free to move vertically.



Load Buckling Factor is 2.6, which is smaller than 4 but happens on 1/2" wall, which can be easily increased.

Then, besides bracing the top and the bottom of the tank, the top part of the wall should have the thickness increased from 1/2".

8. Conclusion

Having:

- a flat roof,
- stereo wires supported directly from the vertical cylindrical walls of the tank,
- electronics at the top of the roof accessible to people, and
- space frame structure supporting the roof,

seem **feasible**, as long as some requirements are met:

- bracing the top of the tank wall,
- bracing the bottom of the tank wall, and
- increasing thickness of top part of the vertical cylindrical wall from 1/2".

Further and more detailed analysis is required to determine the bracing needed and the appropriate thickness of the wall. The analysis should include all 3 different loading conditions: full of liquid (for the hydrostatic test), empty and with the wire load (at the end of the assembly), and full of liquid plus the load from the wires. It should also include the loads from cathode planes and field shaping cage.